DRY MATTER YIELD, IN VITRO DIGESTIBILITY, PERCENT PROTEIN, AND MOISTURE OF CORN STOVER FOLLOWING GRAIN MATURITY

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Past research and practical experience have shown that the stover of corn (*Zea mays* L.) can be used successfully as a roughage and energy source for ruminant animals. The present paper describes three experiments designed to study agronomic aspects of stover utilization. Specifically, the objectives were: (1) to study the rate of moisture loss from stover before and after grain harvest; (2) to measure the variability among commercial hybrids in stover quality and yield; and (3) to examine the relationships between grain and stover yield, and between grain and stover moisture percentage. Averaged across hybrids, 38% of the above-ground dry weight of corn was stover, including stalk, leaf, husk, and shank. At grain maturity, all adapted commercial hybrids produced stover dry matter yields in excess of 4,500 kg/ha with an in vitro digestible dry matter (IVDDM) in excess of 52%. Lower yields of stover dry matter and stover IVDDM were evident for certain nonadapted, or nonrecommended hybrids. Within recommended hybrids there was a nonsignificant correlation between grain yield and stover yield. Percent IVDDM of the stover declined at a rate of 1.5%/wk following grain physiological maturity. Protein content of stover averaged 4.5% and was unaffected by hybrid or date of harvest. No relationship was evident among hybrids between percent stover moisture at harvest and percent grain moisture. The mean percent stover moisture, after adjustment by covariance to 30% grain moisture, was 57.8 with a standard deviation across hybrids of 11.4%. Stover dried at an average rate of 1.0 g water loss per 100 g fresh weight per day during the grain maturation period. Differences among hybrids in percent stover moisture at a common grain moisture were primarily a result of differences in the date at which stover began to dry below its initial moisture content of 80%. Grain harvest with a standard corn combine increased the drying rate of stover to approximately 1.5 g water per 100 g fresh weight per day during the period after grain maturity.

Les recherches déjà effectuées et l'expérience ont montré que les tiges de maïs (*Zea mays* L.) pouvaient être employées comme fourrage et comme source d'énergie pour les ruminants. La présente étude décrit trois expériences ayant pour but d'examiner les aspects agronomiques de l'utilisation du fourrage de maïs. Les objectifs étaient précisément: (1) d'étudier la perte d'eau du fourrage avant et après la récolte des grains; (2) de mesurer la variabilité de la qualité et du rendement en fourrage entre les hybrides commerciaux; et (3) d'étudier les rapports entre le rendement en grains et en fourrage, et entre la teneur en eau des grains et du fourrage. Pour l'ensemble des hybrides, 38% du poids sec des parties aériennes du maïs étaient composés de fourrage (tiges, feuilles, enveloppes, et pédoncules). A la maturité des grains, tous les hybrides commerciaux adaptés ont donné des rendements en matière sèche de plus de 4,500 kg/ha de fourrage ayant une digestibilité in vitro (DMSIV) de plus de 52%. Certains hybrides non adaptés, et non recommandés, ont donné des rendements en fourrage sec et une digestibilité plus faibles. On a obtenu une corrélation non significative entre le rendement en grains et le rendement en fourrage chez les hybrides recommandés. Le coefficient de DMSIV du fourrage a diminué de 1.5% par semaine à partir de

la maturité physiologique des grains. La teneur en protéines du fourrage s'établissait en moyenne à 4.5%, peu importe l'hybride ou la date de récolte. L'étude n'a révélé aucun rapport évident entre la teneur en eau du fourrage à la récolte et la teneur en eau des grains parmi les hybrides. La teneur moyenne en eau du fourrage, après correction par covariance à une teneur en eau des grains de 30%, était de 57.8%, l'écart-type entre les hybrides étant de 11.4%. Le fourrage a séché au rythme moyen de 1 g de perte d'eau par 100 g de poids frais par jour au cours de la période de maturation des grains. Les écarts, entre les hybrides, de la teneur en eau du fourrage, pour une même teneur en eau des grains, provenaient principalement de l'écart entre les dates auxquelles la teneur en eau du fourrage a commencé à diminuer, par rapport à la teneur initiale de 80%. La récolte des grains, au moyen d'une récolteuse de maïs ordinaire, a augmenté le taux de séchage du fourrage à environ 1.5 g d'eau par 100 g de poids sec au cours de la période suivant la maturité des grains.

INTRODUCTION

According to Feeding Standards of the National Academy of Sciences (1970) the stover portion of a corn crop (*Zea mays* L.) has sufficient energy to be used as a roughage feed to mature pregnant beef cows. Colenbrander et al. (1971) reported that corn stover contains sufficient energy for maintenance of dairy heifers and a limited growth rate of 0.5 kg per animal per day.

Ontario fall weather conditions usually do not allow corn stover to dry in the field to a sufficiently low moisture percentage for satisfactory storage as dry feed. Muddy field conditions in the fall and spring, and snow cover in winter make pasturing unsatisfactory. Past unpublished experience has indicated that ensiling may represent the best system of preserving and storing corn stover for overwinter feed.

Although past research has considered the feeding value of corn stover for ruminant animals, very little information is available on the agronomic aspects of stover production. As a result, the following study was conducted with the purpose of (1) measuring the rate of moisture loss from corn stover during the periods before and after grain harvest; (2) characterizing the amount of variability that exists among commercial corn hybrids in dry matter yield, feeding quality, and moisture percentage of corn stover at grain maturity; and (3) examining the relationships between grain yield and stover yield, and between grain moisture percentage and stover moisture percentage, among commercial corn hybrids.

MATERIALS AND METHODS

The study involved three experiments conducted during the growing seasons of 1970 and 1971.

Experiment I was conducted in 1971 only, with the objective of estimating the amount of variation that exists among hybrids for yield, in vitro digestible dry matter (IVDDM), percent protein, and percent moisture of corn stover at grain harvest. The experiment consisted of 22 hybrids, 10 of which were commercial dent hybrids recommended by the Ontario Corn Committee (1971) for above-average performance in the Guelph area. Of the 12 nonrecommended hybrids, four were of later-than-adapted maturity, three were earlier-than-adapted, and the balance were flint-dent crosses of adapted and earlier-than-adapted maturity. The test was undertaken with a plant population of 52,000 plants/ha in 76-cm rows, and was replicated four times in a randomized complete-block design. Each plot measured four rows wide by 6 m long. The plot was overplanted by hand on 7 May and subsequently thinned to ensure a near-perfect stand of one plant per hill.

Twenty-four plants were selected at random from the center two rows of each plot on the date (approximately) when each hybrid reached 80% black layer formation (Daynard and Duncan 1969). The plants were divided into ear (grain plus cob) and stover components and weighed. From the twenty-four plants, stover from six was selected at random and divided into stalk, leaf, and husk. A 60-kernel sample was taken from each plot by removing 10 kernels from the middle of six ears. The plant components were weighed, dried in a forced-air drier for 1 wk at 80 C, and subsequently reweighed. After drying, the 60-kernel sample was combined with kernels shelled from the ear sample and the total weight was used to eliminate grain yield.

The data obtained were used to calculate initial moisture percentages and dry matter yields of stalk, leaf, husk, cob, and grain of the 22 hybrids. Because of differences among hybrids in grain moisture percentage at 80% black layer, all dry matter yields were adjusted by covariance to 30% grain moisture. Grain yields were calculated on the basis of 15.5% moisture. Stover percentage moisture was calculated as the weighted average moisture percentage of its stalk, leaf, and husk components.

The in vitro digestible dry matter (IVDDM) percentage and protein content of stalk, leaf, and husk components were measured for all hybrids of experiment I. IVDDM was measured by the technique of Mowat et al. (1965) and protein determined by Kjeldahl analysis as outlined by Warner and Jones (1966). Percent IVDDM of stover was calculated as the weighted average IVDDM of its three components. Percent protein of stover was calculated in a similar manner.

Experiment II was conducted in both 1970 and 1971 with the objective of measuring changes, with time, in the percent moisture, IVDDM, and protein content of corn stover during the maturation period. The experiment involved seven recommended commercial dent hybrids (Ontario Corn Committee 1971) and one flint-dent cross. The eight hybrids were grown in a randomized complete-block design with four replications. The planting procedure, row spacing, and plant density were identical to those described for experiment I. Eight harvests were taken in 1970 and 1971 at approximately weekly intervals starting the last week of August. Plots were twelve rows wide and at least one row (six plants) was left between subsequent harvest sites. On each harvest date, six plants were removed from each plot and subdivided to obtain fresh and dry weight of all components as in experiment I. After the final weighing, the stover samples were retained for four of the hybrids at three harvest dates in 1971. The samples were subsequently analyzed for protein content and percent IVDDM by procedures identical to those described for experiment I.

Experiment III was designed to follow the daily fluctuations in percent stover moisture after grain harvest with a standard corn combine head. Samples were taken from a field of the hybrid Stewarts 2606, which had been machine-planted in 81-cm rows at a plant population of approximately 42,000/ha. Samples of corn stover were taken at four sites, selected at random from within the field, at daily intervals. Sampling began at grain harvest, approximately 8 days after grain physiological maturity, and continued for 22 consecutive days. Collections were made in the afternoon. Samples were weighed, dried in a forced-air oven at 80 C for 24 h, reweighed, and the data used to calculate initial moisture percentages of the stover samples.

All experiments were conducted near Guelph, Ontario, on well-fertilized sites. Both seasons were characterized by an adequate distribution of rainfall throughout the growth period. Near-perfect weed control was obtained chemically for all experiments.

RESULTS AND DISCUSSION

Yield

Results of experiment I showed that, on the average, 38% of the final above-ground dry matter of corn was stover (Table 1). Approximately 50% of the mature total plant dry weight was grain; however, as had been observed by Bryant and Blaser (1968), significant differences were evident among hybrids in the relative distribution of final plant dry weight.

A portion of the difference among hybrids in stover dry matter yield could be attributed to differences in grain yield (Fig. 1). The linear correlation coefficient between grain yield and stover yield was significant ($r = 0.42$, $P < 0.05$) when calculated for all 22 hybrids. However, the corresponding correlation coefficient among recommended hybrids was nonsignificant ($r = -0.05$). Recommended hybrids generally yielded more grain and stover per hectare than their nonrecommended counterparts. Within recommended hybrids, grain yield was not a useful indicator of the relative stover yield of a given corn hybrid.

Table 1. Mean distribution of above-ground plant dry matter for 22 corn hybrids (experiment I)

Plant component	Mean % of plant dry wt
Leaf	12.0±3.1*
Stalk	17.6±2.9
Husk	8.9±2.6
Stover	38.5±5.0
Cob	11.8±3.3
Grain	49.7±5.5
Ear	61.5±4.8

*Confidence limits ($P < 0.05$) among hybrids.

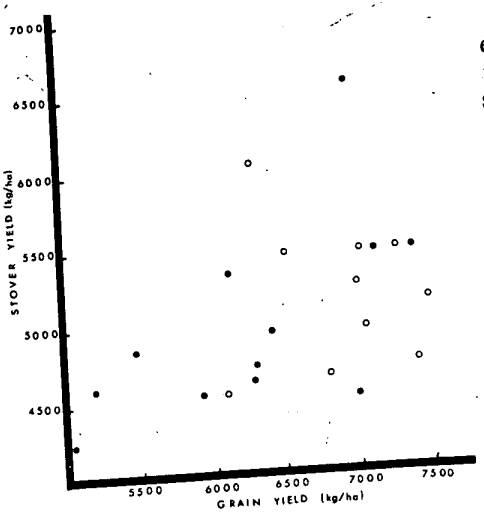


Fig. 1. Grain yield and stover yield of 22 hybrids: O, recommended hybrids; ●, non-recommended hybrids (experiment I).

Percent IVDDM

A wide range of IVDDM was evident for the leaf, stalk, and husk components of the 22 hybrids examined in experiment I (Fig. 2). IVDDM of the stover ranged from 42 to 63% at 30% grain moisture. However, all recommended hybrids combined IVDDM values in excess of 52% with stover dry matter yields above 4,500 kg/ha to produce yields of stover IVDDM generally in excess of 2,600 kg/ha. Although a greater range in percent IVDDM was evident among non-recommended hybrids, no tendencies were apparent for any particular group of these hybrids, i.e., early dents, late dents, or flint-dent crosses, to be characteristically different in IVDDM than the recommended dent hybrids.

Results of digestibility determinations for experiment II showed a significant decline in IVDDM at a rate of 1.5%/wk for leaf, stalk, and stover during the 2-wk period immediately after grain physiological maturity (Fig. 3). Cummins (1970) observed a much more variable rate of deterioration that appeared to be inversely related to rainfall distribution.

Percent Protein

Percent protein of stover was unaffected by hybrid (experiments I and II) or date of harvest (experiment II). The mean percent protein of all hybrids at all harvest dates was 4.5%, which is less than the estimate of 5.9 cited by the National Academy of Sciences (1970).

Percent Moisture

Among the 22 hybrids grown in experiment I, the linear correlation coefficient between stover moisture, before adjustment by covariance, and grain moisture was nonsignificant. The range in percentage stover moisture after adjustment to 30% grain moisture was 50.4–65.0 among recommended hybrids, and 50.4–70.1 among all hybrids (Table 2). Although one flint-dent hybrid, Stewarts 2300, was characterized by an unusually high stover moisture percentage (70.1) at 30% grain moisture, no general tendency was evident for flint-dent hybrids or the other two classes of nonrecommended hybrids (early dents, late dents) to differ in stover moisture percentage from their recommended counterparts.

As in experiment I, significant differences in percentage stover moisture at 30% grain moisture were apparent among the eight hybrids in experiment II. Although hybrids

Table 2. Percentage moisture of stover and total plant for 10 recommended hybrids and 12 non-recommended hybrids at 30% grain moisture (experiment I)

	All hybrids		Recommended hybrids	
	Stover	Total	Stover	Total
High	70.1	50.6	65.0	48.1
Low	50.4	37.9	50.4	38.5
Mean	57.8	42.8	57.4	42.1
SE (mean)	2.2	1.1	2.2	1.1
SD (hybrid)	11.4	6.4	11.4	6.4

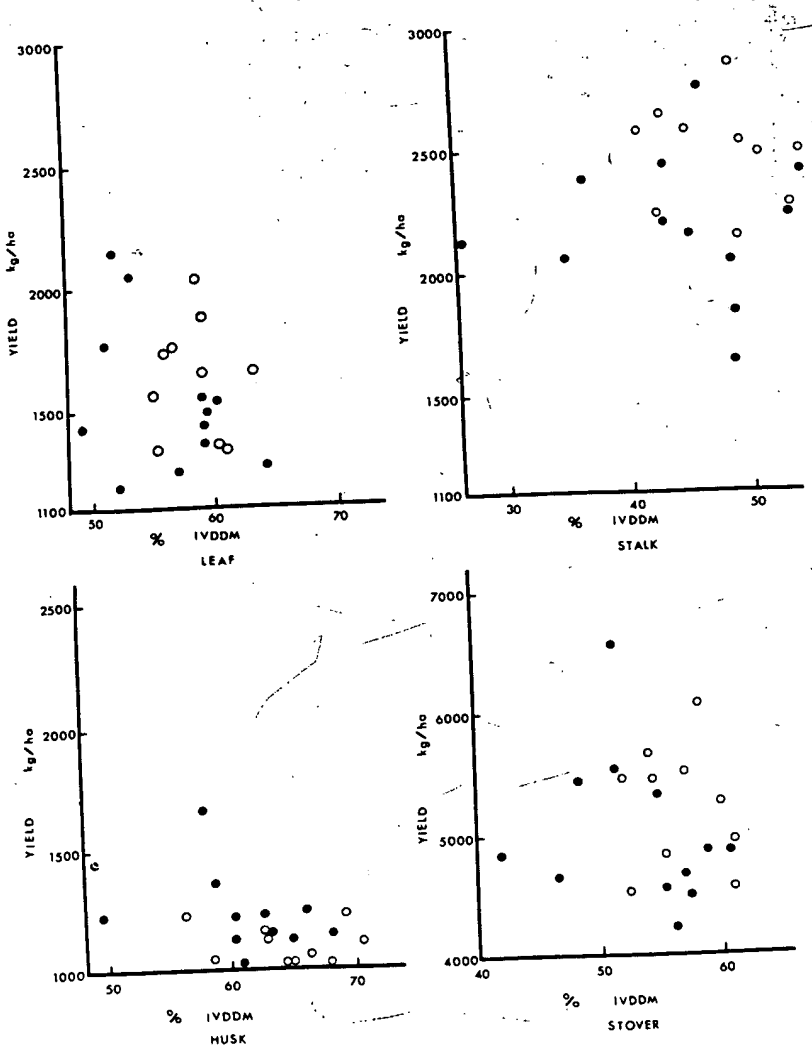


Fig. 2. Percentage IVDDM of stover and its components in relation to their respective dry matter yields: ○, recommended hybrids; ●, nonrecommended hybrids (experiment I).

did differ in the amount of moisture loss during the period before and after grain maturity, the major differences among hybrids in percent stover moisture were a result of differences in the date at which stover began to dry below its initial moisture content of 80% (Fig. 4). There was no significant difference in drying rate between years; stover dried at a mean rate of 1.0 g of water loss per 100 g fresh weight per day, averaged across the eight hybrids.

Results of experiment III revealed that the moisture percentage of stover, after grain harvest, was markedly affected by both time and atmospheric conditions (Fig. 5). A linear regression equation calculated between percentage stover moisture, and days after 30% grain moisture, gave a mean

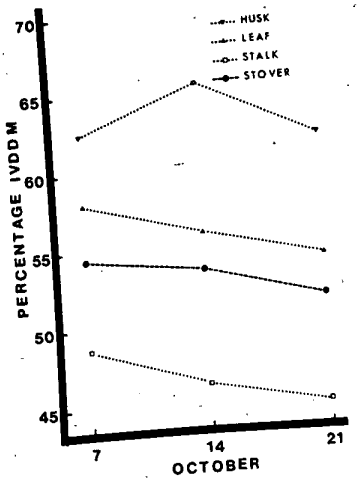


Fig. 3. Average decline in percentage IVDDM of stover and its components, of four hybrids during the 2-wk period after grain maturity (experiment II).

drying rate of 1.5 g water per 100 g fresh weight per day. However, the correlation between measured and estimated values was significantly improved if the linear relationship was expanded to include daily mean vapor pressure deficit (VPD), an estimator of daily drying or wetting conditions (Tetens 1930), as a second independent variable (Fig. 5).

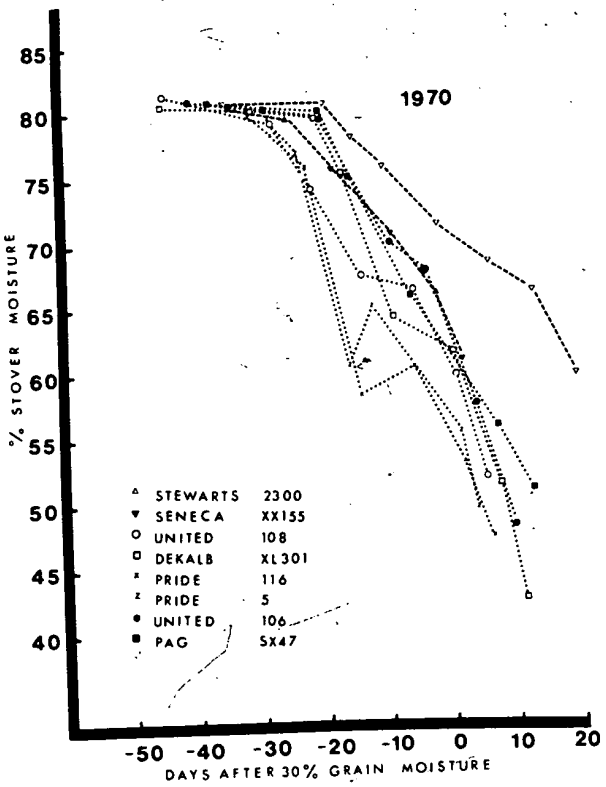
CONCLUSIONS

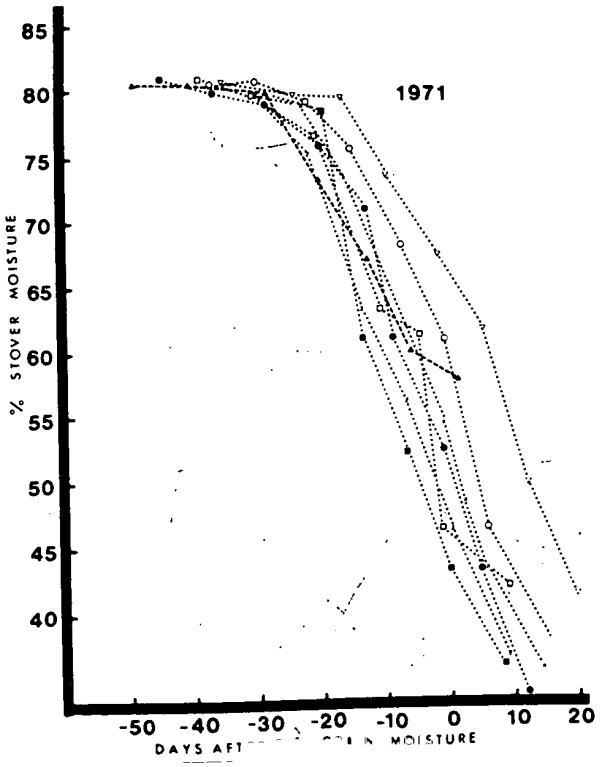
From a feeding and a silage preservation standpoint, desirable characteristics for stover include high moisture percentage, high percent IVDDM, and high dry matter yield following grain harvest. The low or nonsignificant correlations observed in the present study between stover and grain yield, and between stover and grain percentage moisture, suggest that a breeder could make selections for increased stover yield and moisture percentage without antagonizing desirable grain characteristics such as high yield and low grain moisture at harvest.

Present hybrid recommendation extension publications, such as the *Ontario Hybrid Corn Performance Trials* (Ontario Corn Committee 1971) rate relative hybrid performance by such traits as percent grain moisture at harvest, percent broken stalks, endosperm type, relative maturity, and grain yield. In the present study, no predictive relationship was apparent among percent grain moisture at harvest, grain yield, and endosperm type, and either the moisture percentage or dry matter yield of stover. Wysong and Hooker (1966) reported a weak inverse relationship between the concentration of stalk soluble solids, following anthesis, and stalk rot development. This relationship suggests that hybrids with a low percentage of broken stalks would have a high stalk soluble solid content. Because soluble carbohydrate represents a large proportion of the soluble solid concentration of corn stalks (Campbell and Hume 1970), one might expect to observe a significant relationship between percent IVDDM and percent lodging. Although detailed lodging data were not obtained in the present study, no relationship was apparent between the known lodging ratings of the various hybrids examined and percent IVDDM.

In summary, results of the present study show that hybrids differ significantly in the yield, feeding value, and moisture percentage of the stover fraction. Selection is possible for hybrids that combine high grain yield and early maturity with desirable stover characteristics. If stover becomes widely used for feeding purposes, further research is required to define the criteria on which a farmer could base hybrid selection.

Fig. 4. Rate of decline of stover moisture with respect to time of eight hybrids during the period before and after 30% grain moisture. Hybrids with dotted lines (. . .) dried at a significantly different rate than hybrids with broken lines (- - -) (experiment II).


1970
% STOVER MOISTURE
85
80
75
70
65
60
55
50
45
40
STEWARTS 2300
SENECA XX155
UNITED 108
DEKALB XL301
PRIDE 116
PRIDE 5
UNITED 106
PAG SX47
-50 -40 -30 -20 -10 0 10 20
DAYS AFTER 30% GRAIN MOISTURE


1971
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85
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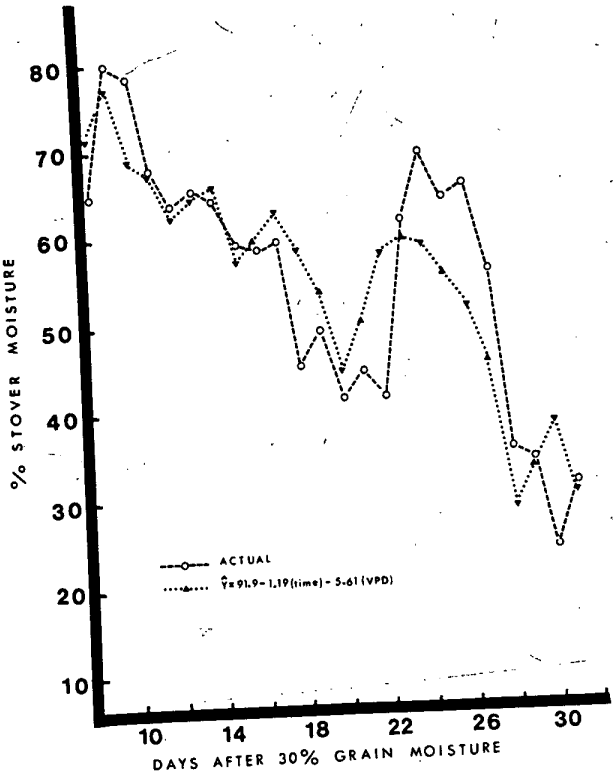

Fig. 5. Actual daily percentage stover moisture in relation to days from 30% grain moisture. Dotted line (. . .) is a plot of calculated percentage stover moisture using the independent variables, vapor pressure deficit, and time (in days) from 30% grain moisture (experiment III).

LITERATURE CITED

BRYANT, H. T., and BLASER, R. E. 1968. Plant constituents of an early and late corn hybrid as affected by row spacing and plant population. Agron. J. **60**: 557–559.

CAMPBELL, D. K. and HUME, D. J. 1970. Evaluation of a rapid technique for measuring soluble solids in corn stalks. Crop Sci. **10**: 625–626.

COLENBRANDER, V. E., MULLER, L. D., WASSON, J. A. and CUNNINGHAM, M. D. 1971. Corn stover silage supplemented with varying increments of energy for growing dairy heifers. J. Anim. Sci. **33**: 1306–1309.

CUMMINS, D. S. 1970. Quality and yield of corn plants and component parts when harvested for silage at different maturity stages. Agron. J. **62**: 781–784.

DAYNARD, T. B. and DUNCAN, W. G. 1969. The black layer and grain maturity in corn. Crop Sci. **9**: 473–476.

MOWAT, D. P., FULKERSON, R. S., TOSSELL, W. E. and WINCH, J. E. 1965. The in vitro digestibility and protein content of leaf and stem portions of forage. Can. J. Plant Sci. **45**: 321–331.

NATIONAL ACADEMY OF SCIENCES. 1970. Nutrient requirements for beef cattle. Washington, D.C. 55 pp.

ONTARIO CORN COMMITTEE. 1971. Ontario hybrid corn performance trials. Ont. Dept. Agr. Food Publ., Toronto, Ontario.

TETENS, O. 1930. Über einege meteorologische begriffe. Z. Geophys. **6**: 297–309.

WARNER, M. H. and JONES, J. B. 19. Determination of total nitrogen in plant tissue using a Technicon kjeldahl nitrogen apparatus. Pages 145–148 *in* Techicon Symposium, Automation in Analytical Chemistry, New York, N.Y.

WYSONG, D. S. and HOOKER, A. L. 19. Relation of soluble solids content and condition to Diplodia stalk rot in corn hybrids. Phytopathology **56**: 26–35.

EFFECTS OF PERCENT MOISTURE AND COMPACTION PRESSURE ON THE ENSILING OF CORN STOVER IN LABORATORY SILOS

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Two experiments were designed to study the effects of moisture percentage and compaction pressure on the ensiling characteristics of corn stover. Both experiments involved the use of airtight laboratory silos of approximately 23-liter capacity. In the first experiment, stover was ensiled under six different vertical pressures ranging from 0 to 169 g/cm² and the density of the silage mass was measured at 0, 3, 10, 40, and 90 days after ensiling. A procedure was developed, using the relationship between vertical pressure and density, to estimate the relationship between vertical pressure and silage depth for various samples of stover silage. In the second experiment stover was ensiled under two vertical pressures, 37 and 169 g/cm² and assessed for several quality characteristics at 0, 3, 10, 40, and 90 days after ensiling. Stover ensiled satisfactorily at all initial moisture concentrations (i.e., 66, 65, 54, and 39% moisture) although at a lower moisture percentage samples required longer to ensile. Mold colonies were quickly eliminated at a *p*H below 4.5 in all silage samples.

Les auteurs ont mené deux expériences dont le but était d'étudier les effets de la teneur en eau et de la pression de tassement sur les caractéristiques de l'ensilage de fourrage de maïs. Dans ces deux expériences, on a employé des silos hermétiques expérimentaux d'une capacité d'environ 23 litres. Dans la première expérience, le fourrage de maïs a été ensilé sous six pressions verticales allant de 0 à 169 g/cm², et la densité de l'ensilage a été mesurée après 0, 3, 10, 40, et 90 jours. Une technique mettant en rapport la pression verticale et la densité a été mise au point afin d'évaluer le rapport entre la pression verticale et l'épaisseur d'ensilage dans divers échantillons de fourrage de maïs. Dans la deuxième expérience, le fourrage de maïs a été ensilé sous deux pressions verticales, soit 37 et 169 g/cm², et l'on a évalué plusieurs de ses caractéristiques qualitatives après 0, 3, 10, 40, et 90 jours. L'ensilage a été satisfaisant à tous les pourcentages d'eau initiaux (66, 65, 54, et 39%) bien qu'à faible pourcentage d'eau il fallait plus de temps pour parachever l'ensilage. Les colonies de moisissures ont été rapidement éliminées à *p*H inférieur à 4.5 dans tous les échantillons.

INTRODUCTION

The use of corn (*Zea mays* L.) stover as a source of roughage feed may have a role in Ontario agriculture. This material can be successfully used for overwintering beef cows (Beattie 1971) and for growing dairy heifers (Colenbrander et al. 1971*b*). Ontario fall drying conditions usually do not allow stover to be harvested as dry feed and pasturing is not practical because of mud and snow cover. It has been reported by Leask and Daynard (1973) that stover can be harvested at percentage moistures greater than 60 depending on the hybrid selected and the date of harvest. Apparently sufficient moisture is available to harvest and store this material as silage. The purpose of this study was to measure the ensiling properties of corn stover as affected by stover moisture percentage and vertical compaction.

MATERIALS AND METHODS

The laboratory silos used in this study consisted of 23-liter drums (5-gal lug seal drums, Continental Can Co., Ltd., Toronto, Ontario) lined with 2-mil polyethylene bags (Fig. 1).